(2)

ARL-STRUC-TM-560

AR-007-095

AD-A256 318

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Aircraft Structures Technical Memorandum 560

AN INVESTIGATION ON THE IMPROVEMENT OF SPATE SIGNAL BY MEANS OF A SUITABLE SURFACE COATING

by

N. RAJIC

92-27840

Approved for public release.

JULY 1992

AR-007-095

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORY

Aircraft Structures Technical Memorandum 560

AN INVESTIGATION ON THE IMPROVEMENT OF SPATE SIGNAL BY MEANS OF A SUITABLE SURFACE COATING

by

N. RAJIC

SUMMARY

An investigation on the feasibility of improving SPATE signals by surface coating has been carried out. Several substrate/coating combinations were considered in a mathematical model simulating constant strain amplitude cyclic loading conditions. It was found that it is possible to intensify the thermal emission of materials commonly used in SPATE analysis, such as mild steel and aluminium by coating with a material of improved thermoelastic properties. However, practical concerns such as cost, structural integrity of the coating under cyclic loading and the effects of the coating process on the internal stress state of the specimen need to be further investigated.

DSTO AUSTRALIA

A-1

POSTAL ADDRESS: Director, Aeronautical Research Laboratory
506 Lorimer Street, Fishermens Bend 3207
Victoria Australia

CONTENTS Page No.

1.	INTRODUCTION	1
2.	BACKGROUND	2
3.	RESULTS	3
3.1	Dense alumina coating	4
3.2	Bronze coating	4
3.3	Epoxy coating	4
3.4	Aluminium substrate	5
4.	DISCUSSION	5
4.1	Coating thickness effects	5
4.2	Peak response amplification	6
4.3	Non-dimensioning the results	7
4.4	Coating problems	7
5.	CONCLUSIONS	8
6.	ACKNOWLEDGMENTS	8
	REFERENCES	9
	TABLES	10-11
	FIGURES 1-7	12-18
	DISTRIBUTION	
	DOCUMENT CONTROL DATA	

1. INTRODUCTION

An area of potential improvement in current SPATE work is that of increasing signal to noise ratios. Some of the possible ways of accomplishing this are as follows;

i) Reduce the the noise component of the signal,

ii) Utilise higher stress levels,

iii) Maximise the surface emissivity of the specimen,

iv) Increase the specimen ambient temperature,

v) Optimise the load-time history,

vi) Coat the specimen with a material which has an improved thermoelastic response.

In considering (i), two significant contributors to noise in SPATE signals can be identified; (a) emission of IR radiation from bodies in the vicinity of the specimen and (b) random electronic noise generated by the circuitry within both the SPATE detector head and post processing equipment. Extraneous IR radiation (not emanating from the subject) can be eliminated by shielding the work area (SPATE head and specimen). The problem of electronic noise is intrinsic to the hardware and while non-random noise can be reduced by signal processing, random noise which is also white cannot. In discussing the other options, it is assumed that the noise component of the signal is independent of the signal intensity, which for the noise sources discussed above will be true. Intensifying the signal by increasing the specimen load stress (ii) is probably the most convenient approach. However, the fatigue life of the specimen under cyclic loading is reduced under an increased load stress and this in effect defines a limit to the benefit available from this option. The application of high emissivity paint coatings (iii) has virtually been the standard practice used to enhance IR radiance from specimens (MacKenzie [1]). Specialised carbon-based heat-radiator paints can increase the emissivity of a specimen to approximately .98, which leaves little scope for achieving an improvement in this area (maximum emissivity is 1). Recent work conducted in the area of improving SPATE signals by increasing the ambient temperature (iv) has shown that a doubling of signal-to-noise ratio can be achieved when used in conjunction with suitable high emissivity coatings [2]. A concern with elevated temperature scans however, is the difficulty of obtaining a uniform temperature across the specimen, especially if the shape is complicated. This is a result of both convective heat losses from the surface and a difficulty in applying the heat to the specimen uniformly. The paints commonly used to enhance the emissivity of ambient temperature scans were also found to be unstable at the higher temperatures. Considering option (v), it can be shown that a square-wave alternating load results in a two fold increase in signal-to-noise ratio over a sine wave load form (priv. comm. T.G. Ryall).

This report considers the final option, that of coating the specimen with a material of improved thermoelastic properties. A theoretical analysis of the response of several coating/substrate combinations to constant strain amplitude cyclic loading is conducted over the range of frequencies 0-45 Hz. The individual adiabatic responses of the coating and substrate materials are determined and then used in various combinations in a mathematical model to determine the actual response under cyclic loading conditions. It is assumed that both the substrate and coating are uniform in all directions, such that the strain field is homogeneous.

2. BACKGROUND

No Heat Conduction (Adiabatic)

The dependence of the thermoelastic response of a material on the stress, neglecting second order effects, may be written as;

$$\delta T = \frac{-\alpha}{\rho C_v} T_o \delta\sigma, \tag{1}$$

in which δT is the temperature change within a material resulting from the stress increment $\delta\sigma$, T_o is the ambient temperature, α is the thermal coefficient of expansion, ρ is the density and C_v is the specific heat at constant volume. For a material with a positive thermal coefficient of expansion, the application of a tensile stress results in a drop in temperature.

In this work, we consider the case of a specimen coated with a thin layer of dissimilar material. Hence, given that the coating is thin, we can assume that both the surface coating and substrate experience an identical strain when loaded. It is thus more convenient to express Equation 1 in terms of strain, viz.,

$$\delta T = \frac{-\beta}{\rho C_v} T_0 \delta\varepsilon, \tag{2}$$

where $\beta = (3\lambda + 2\kappa)\alpha$, λ and κ are the Lamé constants, and $\delta\varepsilon$ is the strain increment. The term $\alpha/\rho C_v$ is called the thermoelastic constant and it essentially defines in terms of mechanical and thermal properties the adiabatic thermoelastic response of a material. As we are concerned with strain controlled loading, the strain equivalent form of the thermoelastic constant $(\beta/\rho C_v)$ is of more interest in this analysis, hence $\beta/\rho C_v$ will hereon be referred to as the thermoelastic coefficient, as distinct from the thermoelastic constant $\alpha/\rho C_v$.

Including Heat Conduction (Non-Adiabatic)

Equation 2 defines the temperature rise in a material resulting from elastic loading under adiabatic conditions. However, such conditions are not always obtained under practical loading situations. In the loading case considered in this work (i.e. that of a substrate and coating subjected to an identical cyclically varying strain controlled load), the temperatures generated within these components may be very different. As such, heat conduction will take place between the substrate and coating and hence SPATE will effectively 'see' a signal made up of a weighted contribution from the substrate and coating. Much work has been done in the past to account for this conduction effect. The report by Belgen [3], which was one of the first significant works highlighting the practical feasibility of using IR measurement as a stress determination technique, includes a consideration of heat-conduction effects. The interest in heat conduction became more significant with the increased use of SPATE for composite material analysis (where the temperatures generated in each ply can be markedly different). Wong [4] developed a non-adiabatic thermoelastic theory to quantify conduction effects between plies in composite materials subjected to a cyclic load. A more recent work by Dunn [5] includes this conduction effect in the formulation of an analytically based mathematical model and determines the amplitude and phase of the infra-red SPATE signal for a composite type specimen over a range of loading frequencies (0-45Hz). Specifically developed for use in composite material analysis, this model was modified in the current work to enable it to tackle the substrate/coating combinations considered in this work. In its original form, the model requires the input of the individual adiabatic signal levels generated in the coating and substrate components under the given loading conditions. These levels were determined by adding a stress determination routine to the model, based on the assumption that both the substrate and coating experience an identical strain when loaded.

3. RESULTS

Listed in Table 1 are the materials considered in this work with their corresponding thermoelastic coefficient and the maximum temperature rise achievable when strained to failure. Amongst the most common metallic materials used in SPATE analysis at ARL are mild steel and the various aluminium alloys and for this reason, the properties of these materials were used for the substrate.

Results for both AL2024 and mild steel substrates with coatings of epoxy, dense alumina and bronze are discussed in this work. Whilst a more comprehensive listing of coatings was studied, the results reflected a large degree of similarity in the amplitude and phase behaviour for materials with similar thermoelastic parameters. Hence on the basis that they sufficiently encompass the range of material types and responses, dense alumina, bronze and epoxy coating results are presented.

Table 2 lists the properties used for the substrate and coating materials and Figures 1-7 illustrate the frequency-dependent amplitude and phase behaviour for the combinations of substrate/coating considered.

3.1 Dense alumina coating

Table 1 shows that dense alumina has an adiabatic thermoelastic-response amplitude significantly higher than of the mild-steel substrate. The dynamic analysis also reflected this, where it can be seen from Figure 1 that the signal level of a mild steel specimen with a 1 mm thick coating of dense alumina is some 100% higher than an uncoated specimen (note that the amplitude response is normalised with respect to the adiabatic response of the substrate). This could be readily deduced from Table 1, hence of greater consequence is the thickness of coating required to negate the lateral heat-conduction to the substrate. Figure 1 shows that within the range of frequencies considered, SPATE effectively does not see a coating of less than 0.01 mm thickness. In fact, a 1mm coating is required to obtain the significant advantage of the improved thermoelastic properties of dense alumina. Another interesting observation is the overshoot of the signal apparent at approximately 10-15 Hz. This overshoot amounts to about 7% above the adiabatic (high frequency) signal level possible with this material combination. It should be noted that the term 'overshoot', as used in this work, refers to the amplitude response level above which would occur for the same material tested at a loading frequency sufficiently high to satisfy adiabatic conditions.

Figure 1b illustrates the phase difference between the specimen response and load signal. The maximum signal phase-difference is $+14°$ at approximately 1 Hz. It is also interesting to note that the phase undershoots the reference signal phase of $0°$ after approximately 20 Hz for the 1mm coating case.

3.2 Bronze coating

The response of the bronze coating is similar to that of the dense alumina and is essentially a scaled down version showing all of the features discussed previously, see Figure 2a. As in the case of dense alumina, a signal overshoot is apparent at about 10 Hz. The improvement in signal at this frequency over the adiabatic substrate level is approximately 21%. Figure 2b illustrates a similar phase behaviour to that observed in the case of dense alumina.

3.3 Epoxy coating

As expected, the comparatively low adiabatic thermoelastic signal level generated in epoxy attenuates the larger substrate signal level except in the case of a thin 0.01 mm coating which is effectively not seen by SPATE. As in the cases of bronze and dense alumina coatings, signal overshoot is also present in the case of epoxy, however, in this case the overshoot is in the opposite direction, leading to a minimum signal level below that of the epoxy adiabatic level. Most apparent for the .1 mm coating thickness (see Figure 3a), the amplitude of the surface signal is seen to drop approximately 30% below the epoxy adiabatic level over the frequency range 30-45 Hz. It is interesting to note that due to the low thermal conductivity of epoxy, adiabatic conditions for a 1 mm coating exist for any frequency above 1 Hz.

3.4 Aluminium substrate

The results for an aluminium substrate are similar to those for a mild steel substrate when coated with the same materials. Figures 4, 5 and 6 show the amplitude and phase response for coatings of dense alumina, bronze and epoxy respectively.

4. DISCUSSION

4.1 Coating thickness effects

Reducing the coating thickness accentuates the effects of through thickness conduction between the coating and subtrate. It can be seen that even in the case of dense alumina (Figure 1a) which has a significantly higher thermoelastic coefficient than the substrate, a coating of .01 mm is effectively not seen by SPATE. Of course this only applies within the frequency range considered (ie. 0-45 Hz); it would be expected that the alumina response would become more dominant at much higher frequencies. To study the complete frequency response of the thinner coatings requires an extension of the considered frequency range to 10,000 Hz. Figure 7 shows that in the case of a .1 mm dense alumina coating on an AL2024 substrate, through thickness conduction becomes insignificant only as the frequency approaches 1000 Hz.

The results indicate that at least within the range of frequencies commonly used in SPATE analysis (at ARL), a coating of at least 1mm in thickness is required to gain the benefits available from a signal enhancing surface coating. In the case of an attenuating coating, like epoxy for example, a converse argument follows. Generally, the thinner the coating, the higher the signal that results. One exception to this occurs because of the negative overshoot in the signal evident for a .1 mm epoxy coating (see Figure 3a). In this case the signal falls 30% below the epoxy adiabatic level. Comparing this to the response of the 1 mm coating shows that above a frequency of approximately 20 Hz, a 1 mm epoxy coating attenuates the substrate response less than a .1 mm coating thickness. While epoxy coatings are typically not recommended, they may be present on specimens which require SPATE analysis, in which case knowledge of this behaviour becomes important.

4.2 Peak-Response Amplification

The presence of a peak-response amplification (overshoot), as most evident in the case of a dense-alumina coating at approximately 12 Hz, can be attributed to the favourable interaction of the different modes of thermal response at that particular frequency. While the peak-response amplification has been observed to be frequency dependent, it could also be affected by inhomogeneities in the specimen, (ie. stress concentrators). In cases where a specimen contains a stress concentrator, such as a hole for example, the peak response would then vary both as a function of frequency and of location on the specimen. This imposes the limitation that in a practical situation, where the studied specimen contains some form of geometric discontinuity, peak-response amplification may not occur uniformally across the specimen. This could lead to a distortion of the stress pattern obtained from a SPATE scan. This effect needs to be further studied.

In the case of a dense-alumina coating, the overshoot of the combined signal is readily obvious and provides an increase in amplitude of approximately 7% (see Figure 1a). In each case, the amplitude response is accompanied by an inflexion in the gradient of the phase plot which occurs at a slightly lower frequency than at which the maximum amplitude response is observed. Contrary to the beneficial overshoot present in the cases of a dense alumina or bronze coating, the response of the epoxy coated specimen shows a negative overshoot to below the adiabatic level of the epoxy. The overshoot in this case is approximately 30%. The practical implication of this is that knowledge of the frequency behaviour of the system allows one to avoid SPATE operation within the bandwidth encompassing this negative overshoot.

A non-dimensional study of the results with respect to the coating thickness shows that the overshoot frequency in a uniform specimen is related to the thickness of the coating in a Fourier modulus type relationship.

$$F_o = \frac{\chi t}{l^2},$$

where χ is the thermal diffusivity, t is the time and l is the characteristic thickness. Table 3 shows the overshoot frequency corresponding to thicknesses varying from .1 to 1 mm and the parameter $l^2 f$ is seen to be relatively constant over this range. This is an expected result as the Fourier modulus defines the depth of propagation of thermal waves to the characteristic thickness of a body within a certain time. At peak signal level, which is indicated in our case by the maximum overshoot frequency, the time is $1/f$ where f is the frequency of excitation.

From the coatings perspective, the substrate serves as an infinite heat sink and consequently changing the properties of the substrate does not effect the frequency at which maximum response occurs nor the Fourier modulus as long as the substrate retains its relative infinite proportions (in this work, 10 mm was found to be satisfactory). It is possible then to define a F_o number for each coating material considered (independent of substrate material) and from this number, determine the frequency at which maximum overshoot would occur for a particular coating thickness. This is a useful result as the location of maximum overshoot in effect defines the transition between substrate and coating dominated behaviour. In combination with the knowledge that the signal amplitude at maximum overshoot is independent of the coating thickness, the F_o number allows us to define the behaviour of the systems amplitude response at the point of favourable excitation. Table 1 shows the Fourier number for several coating materials.

4.3 Non-Dimensioning the results

Due to the large number of possible coating/substrate combinations, it would be convenient to present the results in a non-dimensional form. It was shown in the preceeding section, that the maximum overshoot frequency can be predicted for a given coating thickness and hence this characteristic can be presented in non-dimensional form, ie. in terms of the Fourier modulus. It should be noted that the parameter $l^2 f$ listed in Table 3 is dimensional and must be divided by the thermal diffusivity of the material to obtain the fourier modulus.

Conducting a non-dimensional analysis on the heat flow equation,

$$\frac{\partial T}{\partial t} - \frac{\kappa}{\rho C}\nabla^2 T = -\gamma T \frac{\partial(\delta V)}{\partial t},$$

where κ is the thermal conductivity, γ is the Grüniesen parameter, δV is the volume variation and ∇^2 is the Laplacian operator, reveals that the only non-dimensional parameter (besides the Fourier modulus) encompassing the important thermoelastic material properties is $E\alpha/\rho C$, which is essentially the Grüniesen parameter $(3\alpha G/\rho C_v)$. While this parameter adequately defines the peak level of the thermal signal emanating from a strained material, it does not account for the transient behaviour of the signal, ie. there is no diffusivity term. Hence in the context of this work, it is not possible to summarise the results in terms of the Grüniesen parameter.

4.4 Coating problems

Whilst there is no doubt a dense alumina coating of at least 1mm in thickness would improve the overall thermoelastic response of a mild steel or AL2024 substrate, it must be recognised that ceramics are relatively unsuitable in cyclic loading applications, particularly if a tensile stress component is present. The presence of a crack in a ceramic coating would lead to erroneous SPATE results (depending on the size of the crack). In fact, by virtue of its high sensitivity to temperature fluctuations, SPATE is often used in a role of defect detection, where in composite materials, delamination is revealed by subjecting the composite to a cyclic loading spectrum and analysing the resultant thermoelastic temperature field for discontinuities. Another point to be considered is the effect the coating process may have on the specimen. Some coating processes such as chemical vapour deposition for example, result in reaction temperatures exceeding the melting point of the substrate materials considered in this work (approximately $1200°C$). Depending on the geometry of the specimen, complicated states of residual stress may be introduced due to the possibly high levels of thermal stress. A further detraction is the relatively high cost of coating a substrate with a ceramic, which is both a result of the expense of the material and the coating process. Given the high risk of failure of the coating, its use would seem to be unjustifiable. Metallic or polymer coatings do not pose the same problems as discussed in the case of ceramic coatings. However, while coating these materials would be relatively simple, inexpensive and structurally sound, the results show that little advantage (from a signal enhancing point of view) can be gained from their use. A bronze coated specimen showed an approximately 20% increase in signal over mild steel alone (1 mm coating) which in itself does not present a significant advantage considering the large coating thickness required.

5. CONCLUSIONS

A theoretical investigation on the feasibility of improving SPATE signals by coating commonly used materials with ones of higher infra-red emittance is presented. Several substrate/coating combinations were considered and the results show that signal improvement can be achieved. In the case of a dense alumina coating on a steel substrate an increase in signal amplitude of 100% was found. It was further shown that a relatively thick coating of 1 mm thickness is required to effect such an improvement, a result which raises practical concerns about the integrity of a thick ceramic coating in a load bearing capacity. Using a bronze coating, it was shown that an increase of 20% in magnitude over a mild steel substrate could be achieved, again requiring a 1 mm thick coating, however without the structural concerns raised in the case of dense alumina. Dynamic overshoot of the SPATE signal was a further important observation leading to the possibility of perhaps tuning the load frequency to optimise signal output. For a given coating material, the thickness of the coating and the frequency at which maximum signal overshoot occurs were found to be related by a relatively constant Fourier modulus. This relationship enables one to determine the frequency at which the transition between lateral conduction and adiabatic dominated thermal behaviour occurs for a given coating thickness.

6. ACKNOWLEDGMENTS

The author wishes to thank Dr A.K. Wong for his support and encouragement throughout this work, Dr T.G. Ryall for his helpful comments and also Mr S.A. Dunn for his source code.

REFERENCES

1. MacKenzie, A.K., Proc. 2nd Int. Conf. on Stress Analysis by Thermoelastic Technique. (London, February 1987) ed B Gasper (Bellingham, WA:SPIE *vol* 731) pp44-53.

2. Rowlands, D.E., Improved SPATE Signal to Noise Ratio at Elevated Temperature. Thermoelastic Working Paper No. 1. Aug 1991.

3. Belgen, M.H., Infrared Radiometric Stress Instrumentation Application Range Study. ISA Trans. 6, pp49-53 (1967)

4. Wong, A.K., A Non-Adiabatic Thermoelastic Theory for Composite Laminates. J. Phys. Chem. Solids. Vol. 52, No. 3, pp 483-494, 1991.

5. Dunn, S.A., Analysis of Thermal Conduction Effects on Thermoelastic Temperature Measurements for Composite Materials. In press, Journal of Applied Mechanics.

6. Engineered Materials Handbook, Engineering Plastics. Vol 2, ASM International 1988.

7. Ashby, M.F., and Jones, D.R.H., Engineering Materials II. Pergamon Press 1986.

TABLE 1:
Thermoelastic parameter values under constant strain conditions.*

Material	Thermoelastic coefficient $\frac{\beta}{\rho C_v}$ Nm/J	Non-dimensional temp rise at failure strain $\frac{\delta T}{T_o} \times 10^{-3}$	F_o $\times 10^{-6}$
Metals			
Al2024	1.966	3.380	
Copper	1.795	.372	.417
Nichrome	.464	.836	
Mild steel	1.875	.662	.559
Bronze	2.25	1.130	.565
Tungsten	3.39	1.660	
7000 series Al	1.378	3.738	
Magnesium	.729	1.136	.468
Titanium	1.158	.642	
Polymers			
PMMA	.528	.030	.622
Nylon 12	.734	.055	.624
Polycarbonate	.338	.030	
Polythene	.584	.013	
Epoxy	.599	.022	.607
PTFE	.064	.008	
Hard rubber	.004	.725	
Ceramics			
Glass	.492	3.250	.613
Diamond	3.510	3.340	.508
Dense alumina	5.210	8.224	.572
PCBN	4.590		

* see references [6] and [7] for source of material property data.

TABLE 2:
Relevant material properties.*

Properties	Al2024	Mild steel	Al_2O_3	Bronze	Epoxy
$\rho(kg/m^3)$	2700	7900	3900	8400	1300
E(GPa)	71	210	390	120	4
$C(J/kgK)$	917	482	795	343	1850
$\alpha \times 10^{-6}(C^{-1})$	24	12	8.5	19	75
$\nu \times 10^{-6}(m^2/sec)$	84.18	14.74	6.45	8.59	0.156

TABLE 3:
Fourier Modulus for dense alumina on AL2024 for varying coating thicknesses

Thickness (l) mm	Max Overshoot frequency (f) Hz	F_o $/(\chi)$
.1	1200	.0833
.2	290	.0862
.3	126	.0885
.4	70	.0892
.5	45	.0889
.6	31	.0896
.7	23	.0887
.8	17.3	.0901
.9	13.7	.0901
1	11.1	.0901

* see reference [7] for source of material property data.

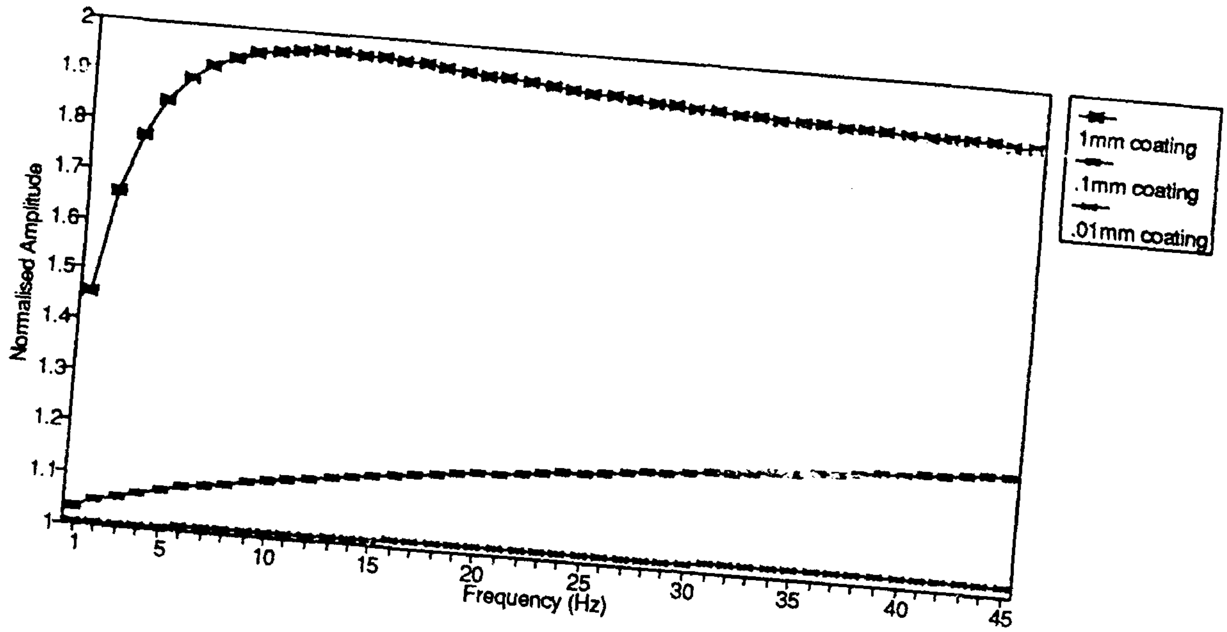

Figure 1(a): Normalised infra red detector amplitude response for a dense alumina coating on a mild steel substrate.

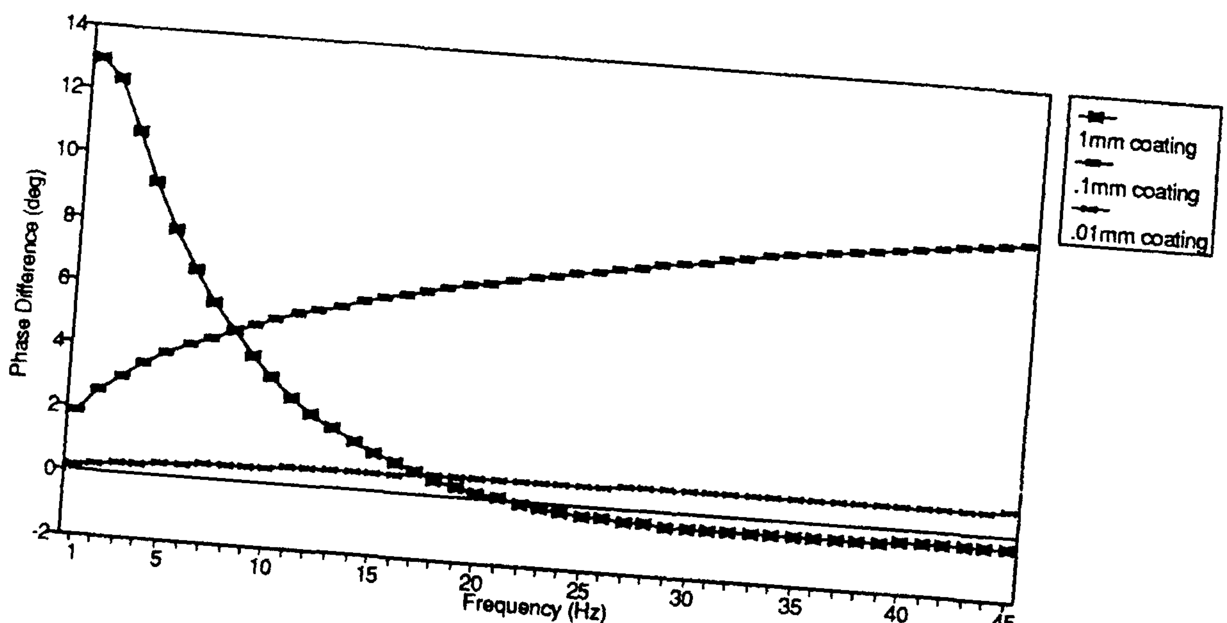

Figure 1(b): Phase response for a dense alumina coating on a mild steel substrate.

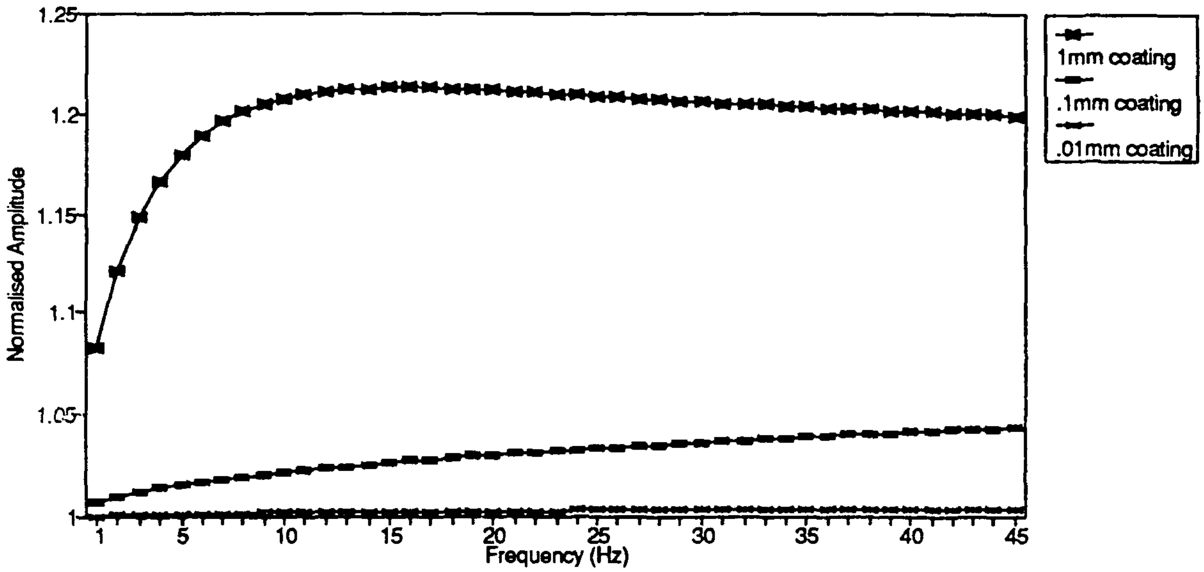

Figure 2(a): Normalised infra red detector amplitude response for a bronze coating on a mild steel substrate.

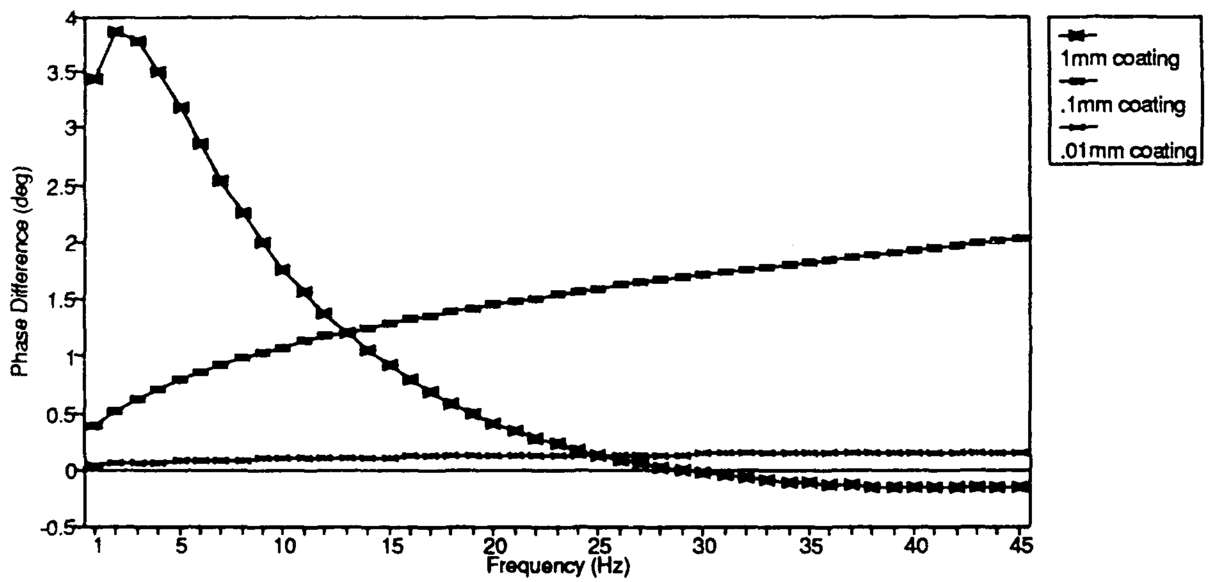

Figure 2(b): Phase response for a bronze coating on a mild steel substrate.

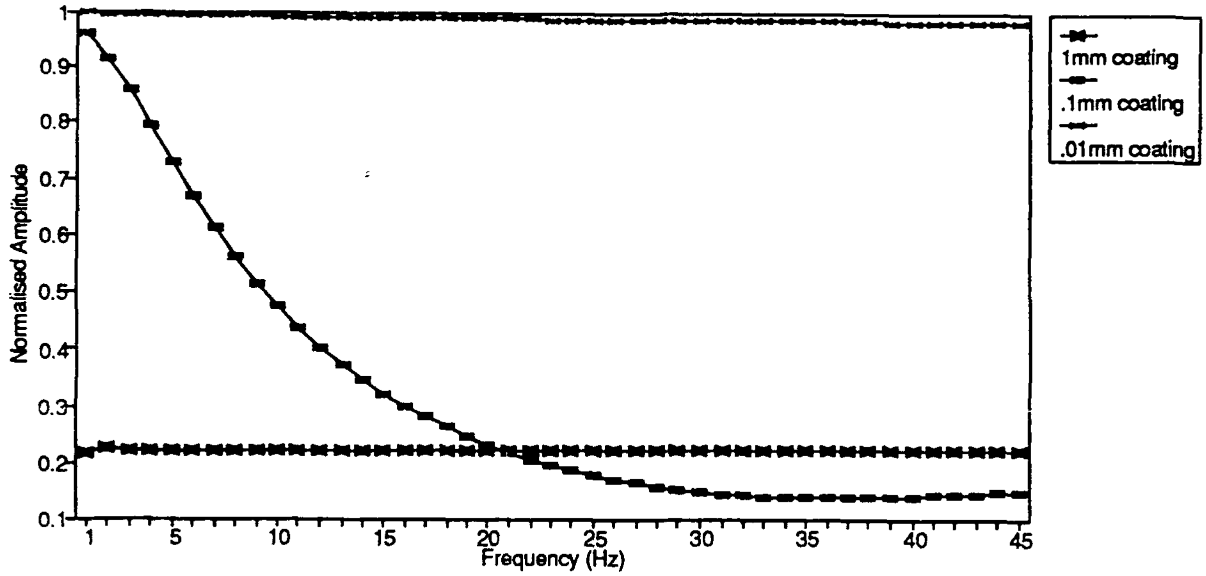

Figure 3(a): Normalised infra red detector amplitude response for an epoxy coating on a mild steel substrate.

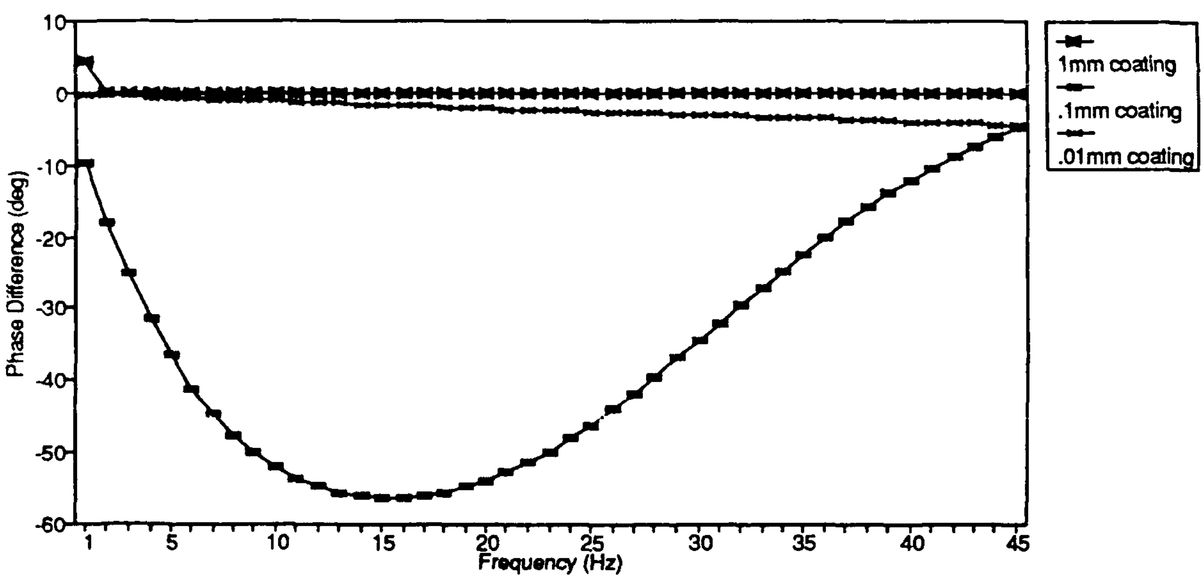

Figure 3(b): Phase response for an epoxy coating on a mild steel substrate.

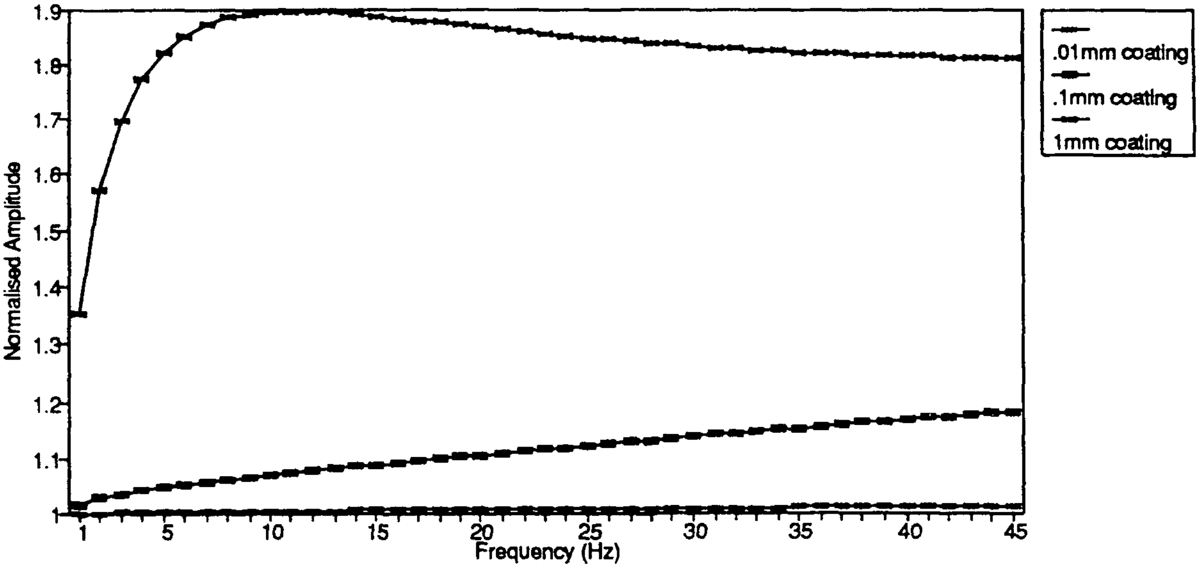

Figure 4(a): Normalised infra red detector amplitude response for a dense alumina coating on an AL2024 substrate.

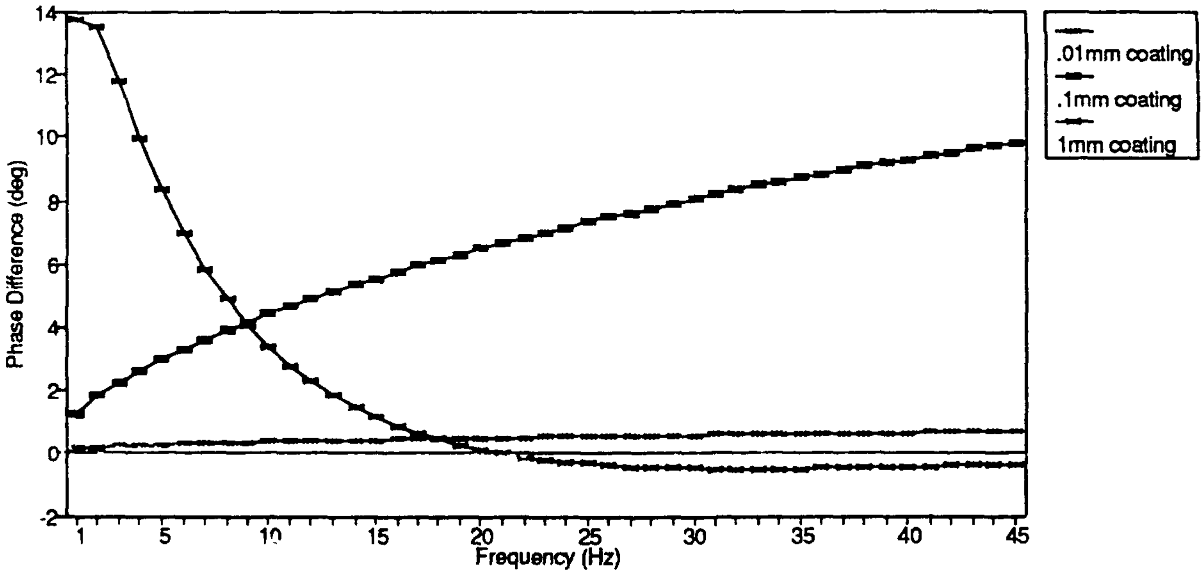

Figure 4(b): Phase response for a dense alumina coating on an AL2024 substrate.

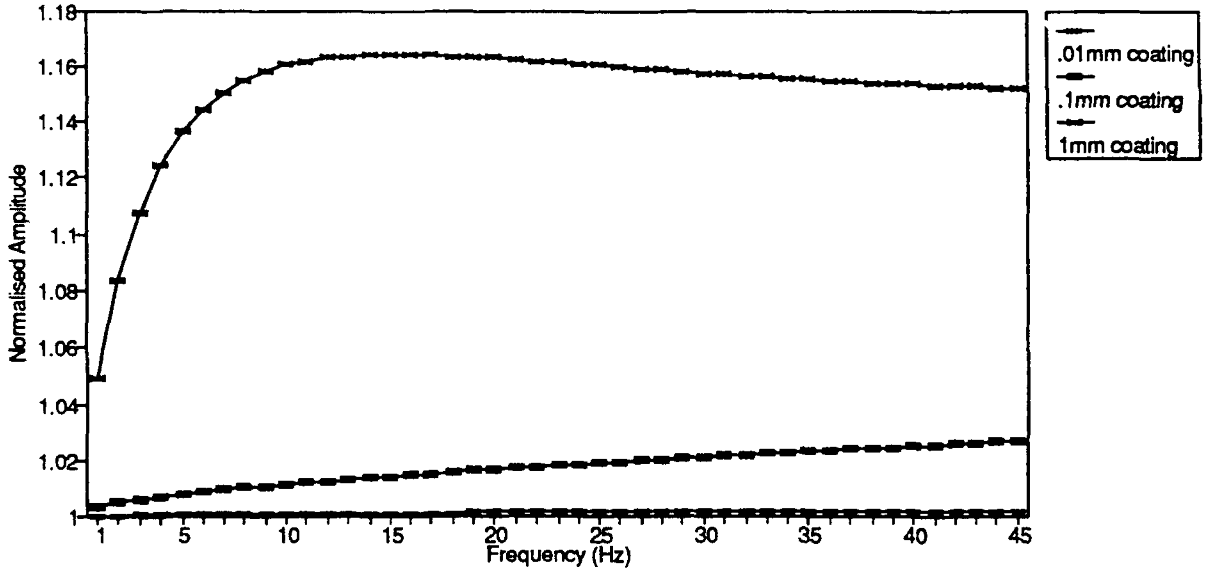

Figure 5(a): Normalised infra red detector amplitude response for a bronze coating on an AL2024 substrate.

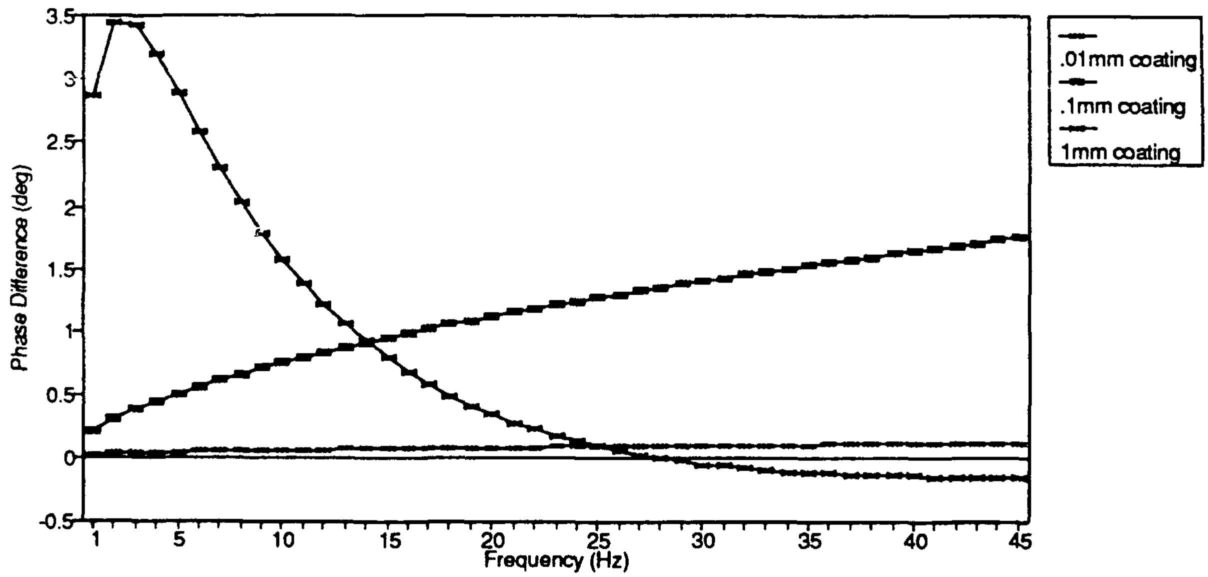

Figure 5(b): Phase response for a bronze coating on an AL2024 substrate.

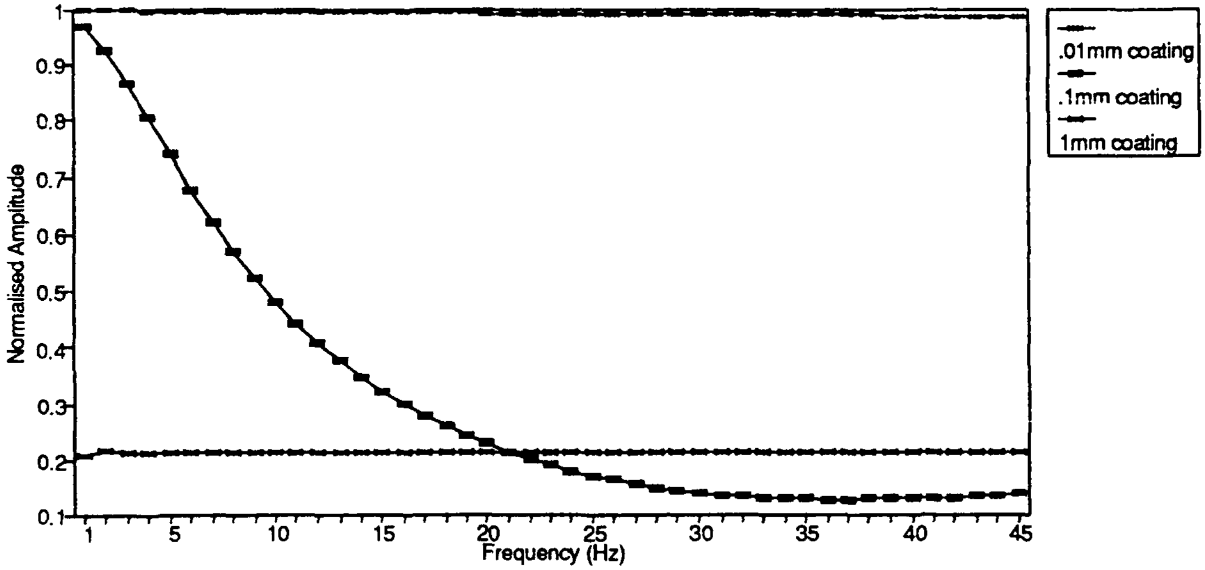

Figure 6(a): Normalised infra red detector amplitude response for an epoxy coating on an AL2024 substrate.

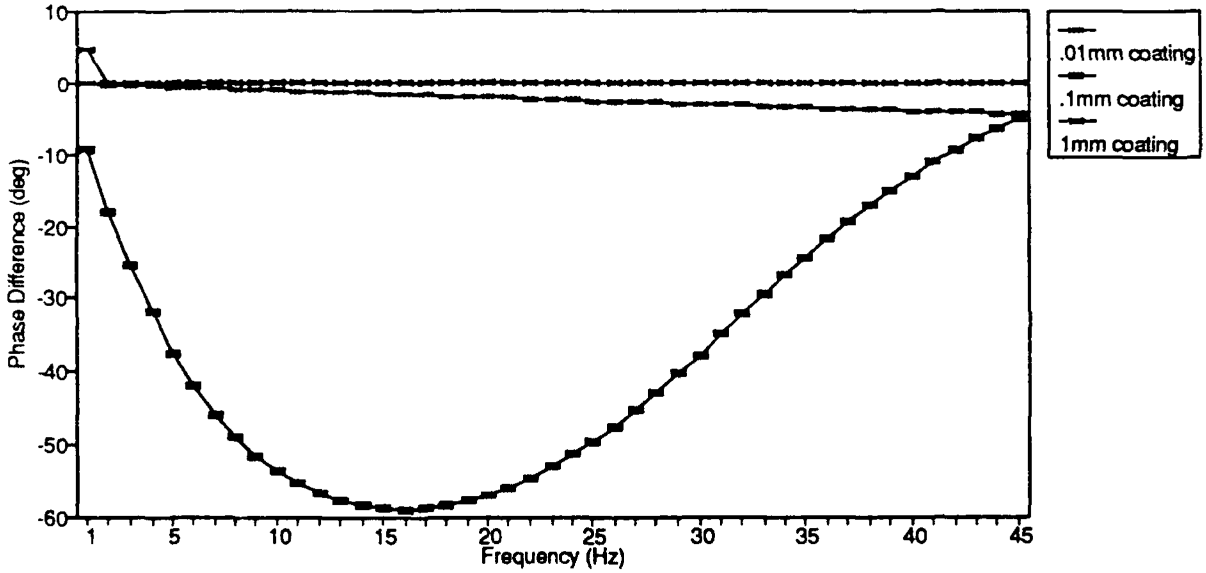

Figure 6(b): Phase response for an epoxy coating on an AL2024 substrate.

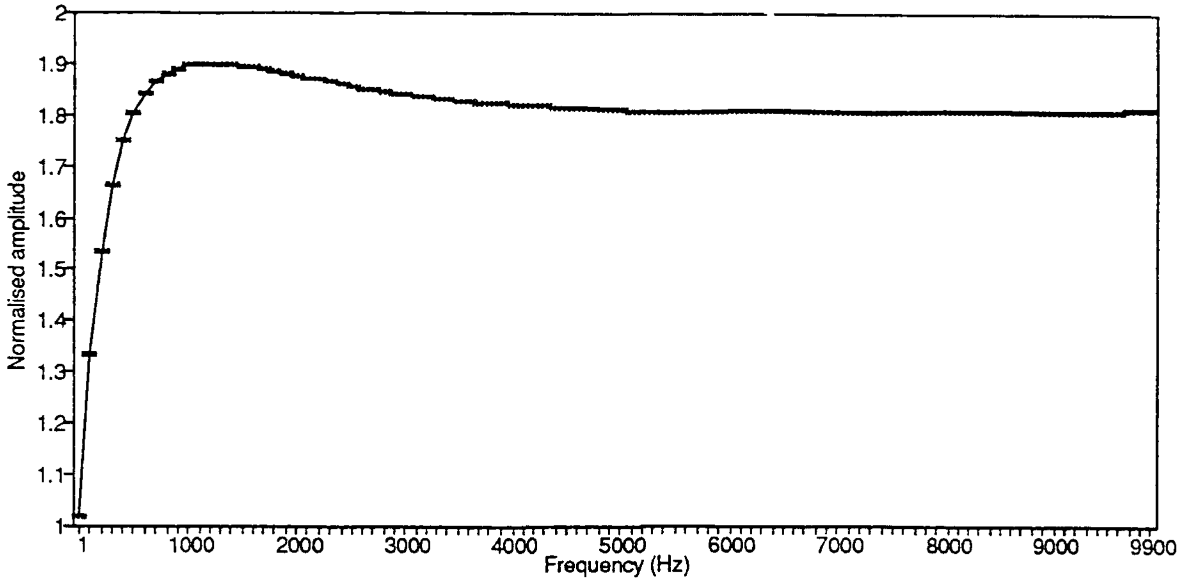

Figure 7: Normalised infra red detector amplitude response for a .1 mm dense alumina coating on an AL2024 substrate over the range of frequencies 0-10,000 Hz.

DISTRIBUTION

AUSTRALIA

Department of Defence

Defence Central

Chief Defence Scientist)
AS, Science Corporate Management)shared copy
FAS Science Policy)
Director, Departmental Publications
Counsellor, Defence Science, London (Doc Data sheet only)
Counsellor, Defence Science, Washington (Doc Data sheet only)
Scientific Adviser, Defence Central
OIC TRS, Defence Central Library
Document Exchange Centre, DSTIC (8 copies)
Defence Intelligence Organisation
Librarian H Block, Victoria Barracks, Melb (Doc Data sheet only)

Aeronautical Research Laboratory

Director
Library
Chief, Structures & Materials Division
Author: N. Rajic
A.K. Wong
S.A. Dunn
J.G. Sparrow

Navy Office

Navy Scientific Adviser (3 copies Doc Data sheet only)

Army Office

Scientific Adviser - Army (Doc Data sheet only)

Air Force Office

Air Force Scientific Adviser (Doc Data sheet only)
OIC ATF (2 copies)

Universities and Colleges

Melbourne
Engineering Library

Monash
Hargrave Library
Head, Materials Engineering

SPARES (5 COPIES)

TOTAL (30 COPIES)

AL 149 DEPARTMENT OF DEFENCE

DOCUMENT CONTROL DATA

PAGE CLASSIFICATION
UNCLASSIFIED

PRIVACY MARKING

1a. AR NUMBER	1b. ESTABLISHMENT NUMBER	2. DOCUMENT DATE	3. TASK NUMBER
AR-007-095	ARL-STRUC-TM-560	JULY 1992	DST 90/039

4. TITLE
AN INVESTIGATION ON THE IMPROVEMENT OF SPATE SIGNAL BY MEANS OF A SUITABLE SURFACE COATING

5. SECURITY CLASSIFICATION (PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF. (C) RESTRICTED (R), LIMITED (L) UNCLASSIFIED (U)).

U	U	U
DOCUMENT	TITLE	ABSTRACT

6. NO. PAGES
20

7. NO. REFS.
7

8. AUTHOR(S)
N. RAJIC

9. DOWNGRADING/DELIMITING INSTRUCTIONS
Not applicable.

10. CORPORATE AUTHOR AND ADDRESS
AERONAUTICAL RESEARCH LABORATORY
506 LORIMER STREET
FISHERMENS BEND VIC 3207

11. OFFICE/POSITION RESPONSIBLE FOR:
SPONSOR DSTO
SECURITY -
DOWNGRADING -
APPROVAL CSMD

12. SECONDARY DISTRIBUTION (OF THIS DOCUMENT)

Approved for public release.

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DSTIC, ADMINISTRATIVE SERVICES BRANCH, DEPARTMENT OF DEFENCE, ANZAC PARK WEST OFFICES, ACT 2601

13a. THIS DOCUMENT MAY BE ANNOUNCED IN CATALOGUES AND AWARENESS SERVICES AVAILABLE TO . . . .

No limitations.

13b. CITATION FOR OTHER PURPOSES (IE. CASUAL ANNOUNCEMENT) MAY BE [X] UNRESTRICTED OR [ ] AS FOR 13a.

14. DESCRIPTORS
Spate 8000 stress analyser
Coatings
Cyclic loads
Stress analysis

15. DISCAT SUBJECT CATEGORIES
2011
1106

16. ABSTRACT

An investigation on the feasibility of improving SPATE signals by surface coating has been carried out. Several substrate/coating combinations were considered in a mathematical model simulating constant strain amplitude cyclic loading conditions. It was found that it is possible to intensify the thermal emission of materials commonly used in SPATE analysis, such as mild steel and aluminium by coating with a material of improved thermoelastic properties. However, practical concerns such as cost, structural integrity of the coating under cyclic loading and the effects of the coating process on the internal stress state of the specimen need to be further investigated.

PAGE CLASSIFICATION
UNCLASSIFIED

PRIVACY MARKING

THIS PAGE IS TO BE USED TO RECORD INFORMATION WHICH IS REQUIRED BY THE ESTABLISHMENT FOR ITS OWN USE BUT WHICH WILL NOT BE ADDED TO THE DISTIS DATA UNLESS SPECIFICALLY REQUESTED.

16. ABSTRACT (CONT).		
17. IMPRINT **AERONAUTICAL RESEARCH LABORATORY, MELBOURNE**		
18. DOCUMENT SERIES AND NUMBER Aircraft Structures Technical Memorandum 560	19. COST CODE 27 211F	20. TYPE OF REPORT AND PERIOD COVERED
21. COMPUTER PROGRAMS USED		
22. ESTABLISHMENT FILE REF.(S)		
23. ADDITIONAL INFORMATION (AS REQUIRED)		